ART. II.—*Plans for Exsection of the Upper End of the Humerus, and for Amputation of the Arm and of the Thigh, with Explanations.* By DAVID PRINCE, M. D., Jacksonville, Illinois. (With 7 Wood-cuts.)

THE importance of appreciating and following the best plans for exsections and amputations cannot easily be overrated. There are three principal considerations which should control the choice of the method in exsections, viz :—

1. Facility of performance;
2. Saving of blood; and
3. Securing the best final result.

Upon the selection of a plan of operating with reference to the facility of performance and the saving of blood, the life of the patient often depends.

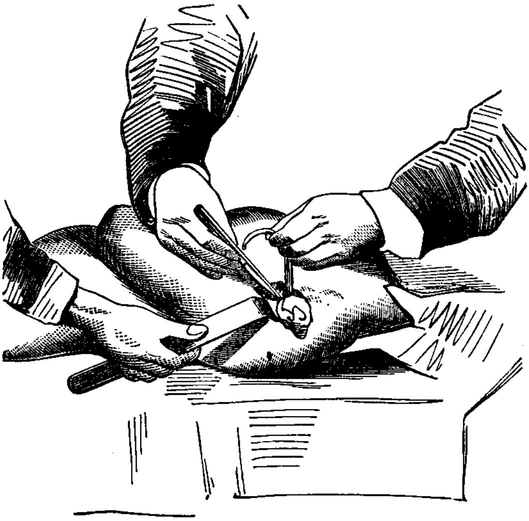
A consideration of secondary importance is the rapidity of the healing of the wound, and this will generally coincide with the choice of those plans which accord with the three principal considerations just enumerated.

I. EXSECTIONS.—It is an important element of the process of removing the upper end of the humerus, to preserve, as much as possible, the muscular and tendinous attachments to the scapula, that they may draw the upper end of the fragment up to the glenoid cavity, and render a moderately firm articulation possible. Without this, the hand is nearly useless, hanging uncontrolled by the patient's side. One of the most important parts to be saved, with reference to the best control of the member, is the long head of the biceps flexor cubiti. This tendon lies closely imbedded in its groove in the bone, and passes to the scapula through the articulation at the shoulder-joint, so that, if it can be saved, it serves not only as an element of lifting to the member beyond, but as a guide to the proper resting-place of the upper end of the fragment. In the ordinary modes of operating, it is not easy to preserve the tendon, without so denuding it of its investments as to render its sloughing probable. Not only is it desirable to preserve this tendon as well as other attachments, but to preserve as much as possible of the periosteum, as the matrix of new bony substance to enter into the reproduction of the joint. To secure these ends, the chain-saw is indispensable in any plan hitherto proposed.

The plan of freely uncovering the neck of the humerus, and passing a broad spatula under it, preparatory to the employment of a common saw, as figured in Erichsen's *Surgery,* and copied in Dr. Stephen Smith's excellent little book on *Operative Surgery,* renders the preservation of the long head of the biceps and any considerable amount of periosteum difficult, if not impracticable. When this tendon, the deltoid muscle, and portions of the bone itself, are carried away by the cause of the injury which necessitated the operation, these considerations, of course, do not apply.

Explanation of Plans.—Fig. 1. An incision is made to the bone, along the central fibres of the deltoid muscle, from its insertion in the humerus

Fig. 1.

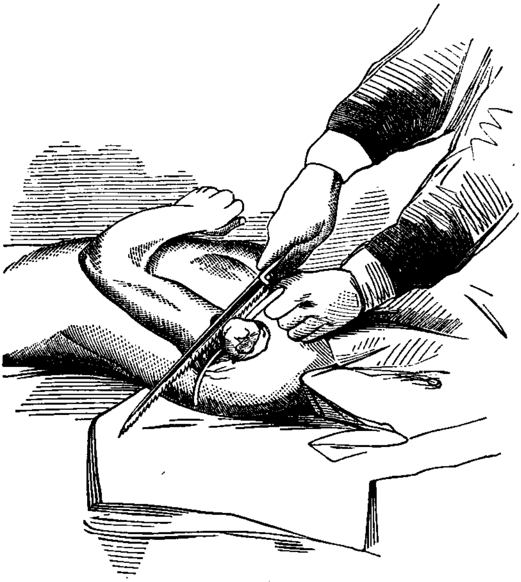


Exsection of Upper Head of Humerus.—An incision has been made along the central fibres of the deltoid, down to the bone, and the retractor is being introduced between the long head of the biceps and the bone.

to the acromion process of the scapula, and, if necessary, the incision is carried an inch or two along the outer border of this process. With the forefinger of the left hand as a guide upon the bone, sufficient dissection is made by the knife, held in the right hand, to enable the operator to insinuate between the long head of the biceps and the bone a probe-pointed, bent, and grooved retractor, as shown in the figure. This retractor is a simplification of a more complicated instrument, to which my attention was first called by that accomplished surgeon, Dr. Charles A. Pope, of St. Louis. The instrument is made of soft iron, well polished, and for use upon the upper extremity should be about eleven inches long, so bent that the distance between the points may be eight inches. About three inches of each end is made in the form of a probe, and it is convenient to have the probe of one end larger than that of the other. The central portion is flattened, and so bent upon the flat as to make a groove upon the convex surface in the figure of a semicircle, and in diameter not more than half an inch. The probe of the retractor having been insinuated between the tendon and the bone, is carried around the bone, and brought out through the wound upon the outside, and pushed through until the grooved central part is under or behind the bone. The riding of the end of the retractor over the skin, as it comes out from under the shaft of the humerus, is facilitated by holding down the skin by the fingers of an assistant, or by a spatula, as shown in the figure.

When the retractor has passed under the bone, and been turned over, it presents the appearance shown in Fig. 2.

Fig. 2.



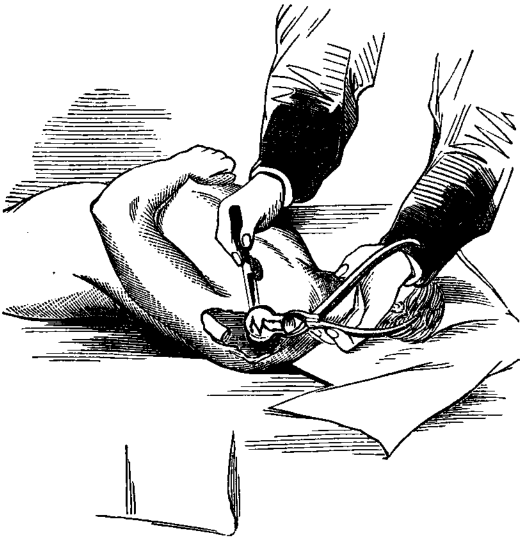
Excision of Head of Humerus.—The retractor has been passed beneath the bone, and turned over, to bring the convex grooved side up, and the saw is being applied.

Fig. 2 shows a common saw applied upon the bone, and working through without any possibility of its teeth touching the soft parts, as the retractor affords complete protection, and presents a groove for the saw to work into as it passes through the bone.

As soon as the bone is divided, it is seized by forceps applied to the lower end of the short upper fragment, and, as the bone is turned up, the periosteum is peeled off by a thick knife or chisel, and the tendon of the biceps is more completely separated from its groove between the tubercles; and in detaching the attachments of the supra-spinatus, infra-spinatus, teres minor, and subscapularis, it is advisable to cut through the bony substance, leaving scales of bone attached to the tendons. This facilitates the production of new bone, and may give these muscles power over the shaft of the humerus in its restored condition.

Fig. 3 shows the completing portion of the last of the three stages of the operation. The head of the bone is seen in the figure completely revolutionized, giving the operator free access to it with his knife for division of soft parts, and his chisel for scaling off the periosteum, carrying with it around the anatomical neck a layer of bone, the better to preserve the relations and functions of the muscles. In removing the head of the humerus for long-existing disease, much of the work of peeling off the periosteum has been done by nature, rendering the task of the operator much more easy. After the removal of the head of the humerus, the glenoid cavity of the scapula may be examined, and, if necessary, more or less of bony substance may be gnawed away with gouging forceps. The linear incised wound is then brought together, and held by sutures and strips of plaster, with reference to primary union; but the plasters should not encircle the arm, on account of the danger of obstructing the circulation in the parts beyond, if there should be much swelling; and the probability of success is somewhat increased by inserting a tube of rubber (Chassaignac's) into the upper end of the wound, to give discharge to fluids from oozing of blood or synovial secretion from the glenoid cavity; and in the absence of this, a quill, or a tube of wood, ivory, or metal may be employed, or a tent, which last should be removed within twenty-four hours. A sling should be so applied as to lift upon the elbow, to aid the deltoid, the biceps, the coraco-brachialis, and the long head of the biceps in shortening, as the upper end of the remaining shaft rises to apply to the glenoid cavity.

Fig. 3.



Exsection of Head of Humerus.—The head has been turned out with a strong pair of forceps, and the knife has detached the bicipital tendon from its groove without dividing it.

It is obvious that in this method of operating, the incised surfaces remaining after the operation are of far less magnitude than those remaining after amputation. The element of magnitude of incision in the preservation of life is on the side of exsection in preference to amputation at the upper end of the humerus. When the humeral artery and its accompanying nerves have not been so injured as to render the preservation of the limb impossible; or its attempt dangerous, from the entrance of sanious fluid into the general circulation, the attempt to save the limb should most surely be made.

The same general plan may be employed in the removal of the upper head of the femur, of the tibio-femoral articulation, or in resections of portions of the humerus and of the femur in their continuity.

In cases in which the periosteum has been separated from the bone in the course of inflammation, leaving the head of the bone in a state of necrosis, it may be broken and removed with even less disturbance of the soft parts than is implied in the introduction of the retractor under the bone.

The great advantage of the plan here explained, over that of sawing the bone with a chain-saw, is the facility of operating, with instruments of little cost, which are easily kept in order.

II. AMPUTATION OF THE HUMERUS AND OF THE FEMUR.—The contest between the methods by flaps and those by circular incisions has been going on two hundred years, since the introduction of flaps by Lowdham, and it is not yet settled.

The choice of plans of operating turns upon the facility with which, in a given case, it may be performed—upon the preservation of the vitality of the parts intended to cover the bone—upon the saving of blood—upon the rapidity of healing, and upon the final result.

1. The flap method has the advantage of the circular, in the length of time required to perform it; but both are so short in skilful hands that this advantage is not important.

2. The preservation of the integument and subjacent tissues from mortification is a point of the greatest importance. For this purpose the capillary circulation must have a thick base. Large flaps of integument may be taken up on the face and neck, and on the upper part of the trunk, with very little underlying substance, and they may live; but upon the thigh they are very apt to die. For this purpose the muscular fascia must be preserved, whatever method is followed; and if the muscular substance, or a considerable part of it, is preserved, the chance of living is better still. The disposition of the integument to slough, when unsupported by sufficient subjacent material, was observed by Graefe, of Berlin, fifty years ago, and hence he advised to cut into the muscles in the first incision in making the circular amputation. Guthrie, the leader of British military surgery, dwells with his peculiar emphasis upon the importance of supporting the capillary

circulation by thickness of parts under the skin saved for the purpose of covering the end of the bone.

Alanson, a century ago, saw the same necessity for supporting the circulation by a sufficient supply of vessels, and hence his difficult method of circular amputation, in which the muscles are cut to the bone, in the form of a hollow cone.

In field surgery another consideration must be borne in mind, viz., that after the operation the patient is often roughly treated, being carried miles in ambulances, and sometimes in common wagons, over rough roads. McLeod, in his *Surgery of the Crimean War*, says:—

> "The circular stumps stood the transit to the rear much better than those formed by the flap method, and thus it would seem that the former mode is better adapted to military practice than the latter. The long, heavy flaps were so knocked about during the land and sea passage, that they often got loose, and ended in sloughing, while the firm, compact stumps made by the circular method were little, if at all, injured."

A favourable opportunity occurred to the writer, in the summer of 1862, to compare the results of circular and flap amputations, as practised in the Army of the Potomac. Going to Richmond in July, after the battle of Malvern Hill, and noting the condition of the amputated limbs, many cases of slough of the rim of integument were noticed, the bone protruding at the extremity of the muscular cone like a stove-pipe out of the top of a Sibley tent, while not a single case of extensive gangrene of a flap was observed. Our surgeons seem to have been governed by the maxim of Sir Astley Cooper, that muscle should not be employed to cover the end of the bone, on account of its tendency to retract, much more than by the consideration of supporting the flap by a thick base of tissue carrying blood-vessels. Hence the circular amputations that fell under my notice had generally been made by dissecting up a rim of integument outside the muscular fascia, and then cutting through the muscular substance, with more or less obliquity, to the bone. In one room in Richmond were sixteen amputated cases of the thigh and arm, eight of one and eight of the other. It so happened that half of these were circular and half flap, and there was not a circular amputation that was not more or less gangrenous, three having sloughed their rims of integument entirely; while of the flap amputations only one case presented any mortification, and that only to the extent of the size of a half dollar. One of the flap cases of the arm united entirely by primary union, except around the ligatures; and two others united in great part by adhesion. Others opened widely, with great swelling, but without gangrene. Had the circular amputations been performed without Sir A. Cooper's fear of muscle over the end of the bone, and with Guthrie's fear of gangrene for want of vascular supply, the result would have been different, but there would have been no primary union. Guthrie gets over the practical difficulty of saving material for vascular support to the integument by making, after the circular cut has been carried through the fascia, a longitudinal incision on the outer side and another on the inner side of the limb, to accelerate the retraction of the integuments with the fascia covering the muscles. After this, the second incision goes to the bone. The result is two rectangular flaps of equal length. It is suspected that some of the bad results of the rectangular flap, as introduced by Teale, in which the anterior flap is long enough to fold upon itself, while the posterior flap is short, have come from the failure to save a sufficient thickness of material under the integument to afford the necessary circulation.

3. *The Saving of Blood.*—It is always desirable that as little blood should be lost as possible, and in enfeebled conditions it is imperative. The tourniquet is the ordinary expedient. The objection to it is, that when the artery cannot be directly compressed upon a bone, its closure is imperfect, and the veins accompanying the artery are obstructed, giving rise to some degree of congestion in the limb beyond, and the blood so arrested in its central progress is of course lost in the limb as it is amputated. Samuel Cooper, in his *Surgical Dictionary*, says that Guthrie lost an officer from hemorrhage while undergoing amputation, though the tourniquet was in charge of a surgeon of ability. "In a case of this kind," says Guthrie, "the surgeon should not continue screwing at the tourniquet, but should quit it, and compress the artery at the pubes." Liston sometimes compressed the femoral or the humeral artery with one hand, while with the other hand he performed the amputation, and this, as he affirms, with the loss of much less blood than if he had relied upon a tourniquet. His common practice, however, was to employ the fingers of assistants, and not to use a tourniquet.

Guthrie's rule was: "When a surgeon has only one assistant, or several bad ones on whom he cannot rely, he should employ a tourniquet."

A convenient method of sawing the bone before dividing the great vessels would save much blood, by enabling the surgeon to restrain the flow of blood by his thumb and finger while the last cut is made, and by diminishing the time during which the open arterial mouths are exposed. It is the chief object of this paper to supply this desideratum, as explained by the illustrations further on.

4. *Rapidity of Healing.*—This depends more upon the nice adjustment of the skin and subjacent areolar tissue than upon any other single element. Muscles are not disposed to unite by *first intention*, so that their contact should be reduced to the smallest extent practicable with due regard to the circulation in the integuments. This consideration is an objection to the transfixing of the limb and cutting out for the formation of an anterior flap, because the muscles are left long, so as to be in the way of the close and easy adaptation of the integument. In the circular method, the prospect of primary union is so small as hardly to call for the use of sutures or for any nice application of plasters, except to keep the cut surfaces from

moving with painful friction upon each other. Those who operate with an intention to get union by adhesion, therefore, adopt some variety of the flap method. Another element is the avoiding of any decomposing substance between the surfaces. Animal or vegetable substances, by the fluids which they absorb, become centres of poisonous productions, from which the adjoining parts only defend themselves by suppuration and the agglutination of tissues by plastic lymph. Metallic sutures absorb nothing and give out nothing, and are therefore, in this regard, superior.

The same consideration has led to the use of metallic ligatures, but they have failed to come into much favour, because, if cut off short, they sometimes fail to imbed themselves in the tissue, and then they make abscesses, and, if left long, they are more in the way than silk or linen ligatures; and, besides, their track is a line of suppuration; pretty much negativing their theoretic advantage.

For the small and superficial vessels, Simpson's expedient of *acupressure* answers the purpose, without interfering with the continuity of coaptation of the cutaneous edges. For the deeper vessels, the metallic ligature will rarely secure union of surrounding surfaces; while, if the threads of vegetable ligatures are carried out at the point selected for the drip of fluids from the deepest portion of the wound, they cannot augment the amount of poison from decomposing material. If they are inclosed in a rubber tube, which at the same time serves for drainage, they are theoretically as well as practically harmless. Dr. Simpson has lately proposed to secure the closure of large vessels by passing through the parts alongside of the artery a common needle threaded with a fine iron wire, by which the needle is subsequently to be withdrawn. Under the ends of this needle a wire is drawn so as to compress the artery, this wire being twisted so that the pressure continues as long as the needle remains in position. This twisting is effected by seizing the head of the needle and the wire which has been passed beneath it, and rotating the needle and accompanying wire, the portion of the loop of wire at the point of the needle remaining stationary. By this means any degree of pressure may be secured. The needle is at the end of two days withdrawn by its wire, and the other wire soon after. The objection that the inner and middle coats of the artery are not cut by the pressure of the ligature is negatived by the explanation that it is the clot, and not the primary adhesion of the walls of the vessels, that secures against hemorrhage; while there may be this advantage, that the portion on the distal side of the loosely embracing ligature shrivels, instead of dying, and thus the little plug of gangrenous material is obviated. The proceeding is a little more tedious than the application of a thread of silk or linen, and, having little or no practical advantage for deep parts, and especially muscular surfaces, it will probably not come into general favour. For atheromatous or ossified arteries, however, which are cut through by the ordinary ligature drawn with its usual tightness, Simpson's expedient of acupressure may prove exceedingly valuable, rendering the old method of cauterizing such vessels unnecessary.[1]

The securing of a drain for the effusions in the deep parts of the wound is often the condition upon which union of the superficial portions is effected and maintained.

In order not to have the surfaces separated by coagula, Dupuytren advised to leave the wound open from six to ten hours, and Liston followed up this recommendation with the claim that by this proceeding adhesion is most likely to take place.

Six hours may be too long, as the parts are sometimes tightly glued by the solidifying exudations, subjecting the patient to great pain in tearing them asunder; and, besides, it is an odious proceeding to disturb a patient a few hours after a severe operation, for any purpose but to afford immediate comfort. If, in consequence of hemorrhage, the wound must be opened, the patient submits to the proceeding as one necessary to save his life; and if there is no hemorrhage, the painful proceeding is unnecessary. If the bleeding is very slight, it will separate only the muscles which would probably have refused to unite without the presence of the layer of clot; and the dissolved clot, mixed with pus, may afterwards escape through the drain established from the first in the plan of dressing.

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[1] *Braithwaite's Retrospect*, Vol. I., January, 1865, contains an article from the *Edinburgh Medical Journal* for September, 1864, by John Dix, Esq., advocating the use of a fine iron wire made to encircle the artery as the track of a comet encircles the sun, the more curved portion of the parabola being near the artery and the expanded portion out upon the skin. The wire has a straight needle upon each end. Each of these is plunged through the flap, entering close to the artery, one on one side and the other on the other side, and emerging through the skin at a considerable distance from each other. The wires are then tied or twisted and a compress placed between the skin and the outer loop made by tying the wire. The wire is afterwards cut close to the skin on one side as for the removal of a stitch, and pulled out by traction upon the other end.

The obvious objection to this expedient is that the delicate wire, by cutting through the softer tissues, may loosen its pressure upon a large artery before it is sufficiently sealed by the solidification of the clot.

The use of an elastic rubber cord applied in this way would be free from this objection, because its size would prevent its cutting and its elasticity would cause it to constrict closely upon the tissues embraced, though they might considerably diminish in volume.

The metallic wire employed in this manner must be very fine in order that it may be drawn out by a pull upon one end, as in withdrawing a suture.

The writer has employed the method upon small arteries with coarser wire, attaching another wire to the loop with which to pull it out through the wound, the loop coming out first and the free ends last.

The wires, when to be withdrawn, are cut even with the skin and withdrawn by the attached wire.

Another source of failure to secure primary union may be the presence of bone-dust from the saw, as it passes through the bone. This is certainly a reason for employing the muslin retractor instead of the fingers of assistants, or for sawing the bone before the soft parts are cut, which, from their position beneath the bone, receive the dust as it falls from the saw. These particles, failing to get washed away, become dead matter in the spaces which they occupy, poisoning the tissues inclosing them, and interfering with primary union.

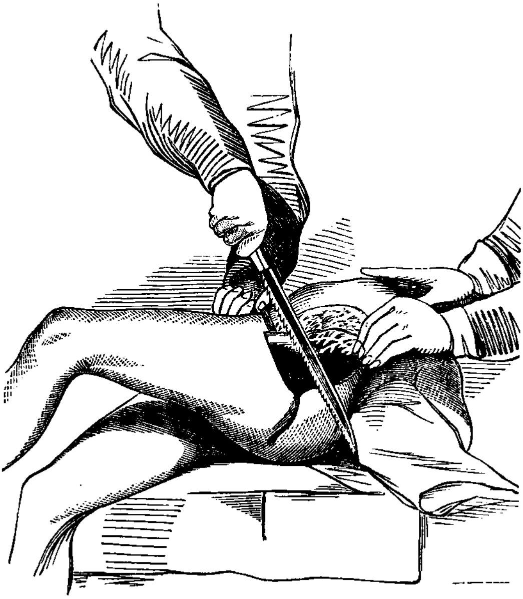
5. *The final result* is best, when the soft parts readily slide over the end of the bone, favouring the formation of a bursa mucosa, the fluid in which makes an easy cushion to protect the end of the bone from pressure. The problem, then, is so to conduct the amputation as most to favour this result. The covering of the end of the bone with a patch of periosteum must obviously tend to this condition. Brunninghaussen, in the beginning of the present century, seems to have been the first to recommend this expedient. The periosteum is peeled up, in connection with its areolar investment, so that it shall not be deprived of its circulation. Samuel Cooper, in his *Surgical Dictionary*, doubts whether the advantage is sufficient to compensate for the trouble of securing it. This will depend very much upon the possession, by the operator, of good scraping forceps for peeling the periosteum from the bony surface.

A more important means is to shape the incisions so that the cicatrix shall not come upon the end of the bone and make a ligamentous adhesion to it, rendering the formation of a bursa slow, if not impossible. This indication, if strictly followed, would rule out circular amputations entirely, and would, in practice, reduce the plans to those in which there is either a single flap, or two flaps of unequal length, so as to bring the cicatrix to one side, and secure the apposition of sound original tissues upon the end of the bone.

The following figures illustrate what the writer believes to be the best method of doing this, in amputations of the humerus and femur, while there is a great saving of blood, and a speed of operation as great as by any other method.

Fig. 4 represents the conclusion of the first stage in amputation through the upper third of the femur. An anterior exterior flap is made of the parts containing only small vessels, by cutting from the surface inward, and cutting the muscles shorter than the integument; and if the expedient of saving the periosteum is practised, this is peeled off from the bone, in connection with the flap. The retractor is then introduced on the inner side, carried under the bone, and over the integument on the outer side, when it is turned over, presenting its grooved surface to the bone. The saw is then applied, as seen in the figure, and worked through the bone into the groove in the retractor, which effectually holds the soft parts from contact with the teeth of the saw. For use upon the thigh, the retractor may be most conveniently of nearly the following dimensions: Length of metal, 14 inches, bent at the extremities so as to span 10 inches; diameter of the groove from one outer surface to the other, half an inch; each probe end is about 3 inches long, one larger than the other, leaving the body 8 inches long.

Fig. 4.

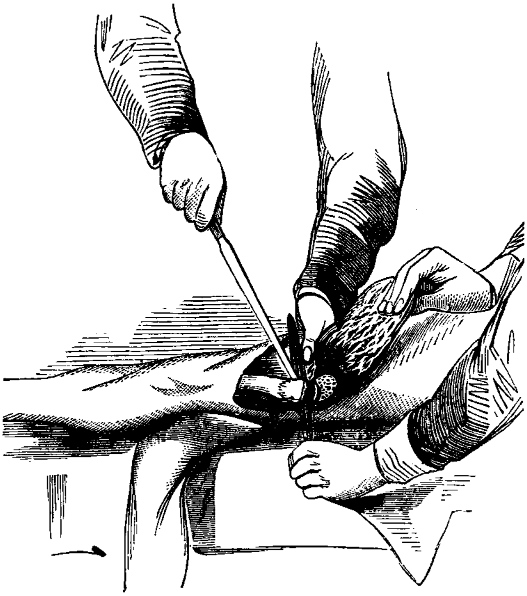


Thigh Amputation in the Upper Third.—The retractor has been placed under the bone, and the saw has been placed on top.

Fig. 5 illustrates the beginning of the third stage of the operation at the junction of the middle and lower third, the sawing of the bone being regarded as the second stage.

The bone is seen to have deviated from the straight line, making an obtuse angle at the point where it has been sawn through. The long knife is being introduced under the bone, along the groove in the retractor, and the operator is grasping the femoral artery between the thumb and fingers of his left hand, the thumb being plunged into the wound for that purpose. As the operator is supposed to stand upon the right side of the patient, the thumb will be turned from himself in amputating the left thigh or the left arm, and towards himself in amputating the right. A lighter shading, bounded by a curved line upon the end of the denuded fragment of bone, and a corresponding one upon the flap as it is seen turned back, represents the periosteum which has been peeled up for the purpose of covering the end of the bone. The same is also shown in Fig. 6. The knife having been passed through, along the groove, an assistant withdraws the retractor, pulling it towards himself, and from the operator.

Fig. 5.



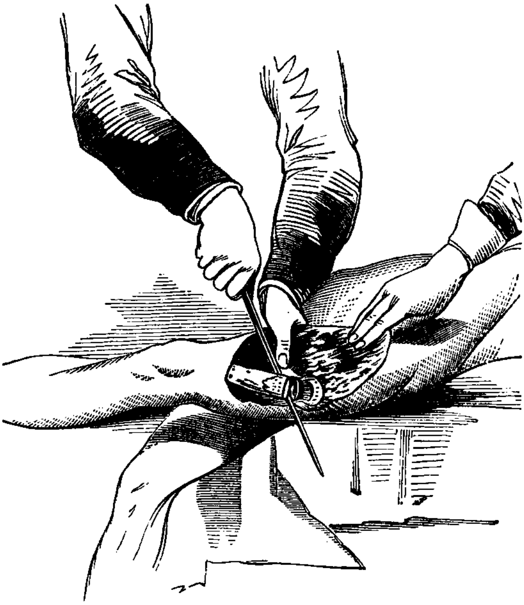
Thigh Amputation at the Junction of the Middle and Lower Third.—The bone has been sawed through, and the knife is being introduced along the groove of the retractor.

Fig. 6 is a prosecution of the third stage, the retractor having been withdrawn, the circulation in the great vessels arrested by the thumb and fingers of the operator, who knows the degree to which he arrests the flow of blood in the artery by the impulse against his thumb, occasioned by the pulsation. These conditions having been secured; the second and final incision is made as much as possible by one sweep of the knife, when the amputated portion of the limb drops by its own weight, and an assistant immediately seizes the chief artery and ties it, and, in rapid succession, secures all the vessels that bleed, by ligature, torsion, or the needle after Simpson's plan.

If the operator is cool and skilful, he controls the bleeding more effectually than can be done in any other method; and if he becomes excited, and fails to control it at all, the vessels are exposed to free access, and can be plugged by putting finger-ends directly upon their open mouths, suppressing the hemorrhage as long as may be desired. The amount of blood lost, when this method is well practised, is surprisingly small.

When the amputation is near the knee-joint, the flap, instead of being an antero-exterior one, should be directly anterior, or antero-interior, to enable the surgeon to get his thumb upon the artery without the interposition of too much muscular tissue.

Fig. 6.



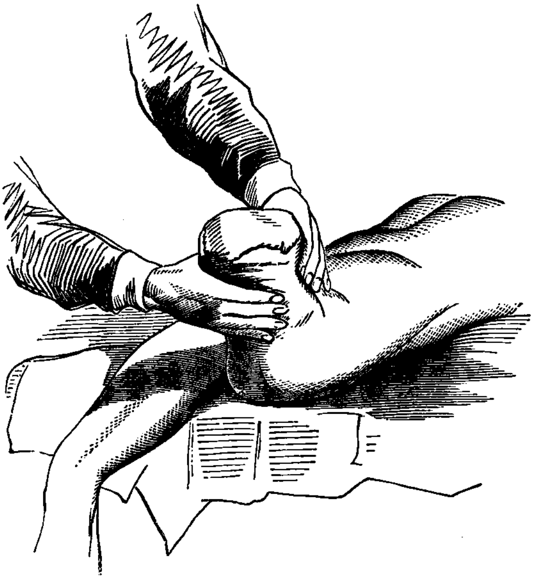
Amputation of Thigh at the Junction of the Middle and Lower Third.—The retractor has been withdrawn by an assistant, and the knife is ready for the final cut. The femoral artery is held between the thumb and fingers of the operator.

In the posterior cut, the operator may make a flap of what length he pleases. He may form his flaps, both anterior and posterior, with square corners, the anterior long and the posterior short, after Teale's plan; though the anterior flap with curved border, and the posterior flap short and made by cutting obliquely out from the point where the bone is divided, will probably come most in favour, in consequence of the greater facility in making the cuts. An objection to Teale's method is the great weight of the long flap, rendering it liable to McLeod's observation that, in rough handling, it may sway about, or, if rendered light by depriving the flap of its subjacent muscles, it may die from want of blood. Another objection is the want of economy of length of stump where length is desirable, the amount of integument needed to form the long rectangular flap rendering it unavoidable to saw the bone higher than might otherwise be necessary.

There can be no advantage in a redundancy of integument, so that if the principal anterior flap meets the line of integument upon the short posterior flap without any tension whatever, the case is better than a superfluous amount of integument.

Fig. 7 represents the appearance of the stump. The end of the bone is covered by the anterior flap, so that a bursa mucosa will easily form over it, and the cicatrix is out of the way of pressure in wearing an artificial limb.

Fig. 7.



Thigh Amputation. Appearance of the Stump.—The cicatrix will be away from the end of the bone.

Thus it is claimed that the method here presented is equal to any other in the facility with which it may be performed, and in the preservation of the vitality of the parts intended to cover the end of the bone; greatly superior to all other methods in the saving of blood; superior to all varieties of the circular method in the rapidity of healing, and in this respect equal to any other variety of the flap method; and in the final result, superior to the circular method and to the plans by flaps of equal length, and equal to any other plan by unequal flaps.

With this estimate of its value, the writer commends the method to the profession.